DSMS Science Operations Concept

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Abstract-The Deep Space Mission System (DSMS) Science Operations Concept describes the vision for enabling the use of the DSMS, particularly the Deep Space Network (DSN) for direct science observations in the areas of Radio Astronomy, Planetary Radar, Radio Science and VLBI.
Scientific research is inherently an innovative activity; the "surprising result" is the best possible outcome. This operations concept establishes a framework that allows scientists to make full use of the DSMS's science capabilities by providing the amount and type of collaboration from DSMS science personnel appropriate to each observation program.

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1. INTRODUCTION

The Deep Space Network (DSN) is primarily used for tracking and communicating with spacecraft in deep space but its capabilities are also successfully used for direct science observations in the areas of Planetary Radar, Radio Astronomy, Very Long Baseline Interferometry (VLBI), and Radio Science experiments with spacecraft. This Operations Concept, currently in review by JPL's Telecommunications and Mission Operations Directorate (TMOD), describes the vision for enabling the use of the DSN for direct science observations. It is intended that this operations concept will be added as an appendix to the larger, "Deep Space Mission System Operations Concept" [JPL internal document in review] whose scope spans the full range of services provided by the DSMS. The Deep Space Mission System Operations Concept will then be used to develop policy and guide new implementations within the DSMS. This concept document recognizes that that policies and procedures related to science observations must be flexible since scientific research is by its very nature an innovative activity.

In the context of DSMS Science, "service" means simply work performed for others, in this case work performed to enable scientists to utilize the DSMS. In this operations concept two distinct types of science operations are covered:

1. **Standard service** science with well-established operations interfaces, and
2. Science observations requiring **customized service**.

Research, which involves significant modification of existing capabilities, is considered an R&D activity and is not covered by this document.

From the "Deep Space Mission System Operations Concept":

The DSMS operations concept is intended to be:

- Visionary - looking down stream 10 years
- All-encompassing, i.e., spanning all of TMOD's operational responsibilities
- The top-level operations concept providing a context and guidance for DSMS subsystem-level operations concept development, as well as, providing insight for DSMS-using projects as they develop their own mission-oriented operations concepts
- A source or reference for operations requirements and a basis for DSMS design and service interfaces
- A living document, updated annually

DSMS Definition

- DSMS is a service system providing mission operations services to deep space flight projects and science services to scientists.
- DSMS is composed of data system elements (i.e., hardware and software) and operations teams which are multi-mission.
- DSMS includes:

1. Ground-based Service Elements - DSN and the Advanced Multi-mission Operations System (AMMOS)
2. Flight-based Service Elements provided by TMOD on a spacecraft

2. DSMS SCIENCE OPERATIONS VISION

The DSN currently is used for scientific observations. The following are "snapshots" of the main features of science operations within the context of DSMS development and its environment at three different times in the future.

Initial State - About 2003

- Mature DSMS Science capabilities are offered to customers as services.
- Capabilities under development are made available as experimental equipment on the basis of collaboration with the developers.
- The operations personnel interface to DSMS mature science capabilities are simple, intuitive, and require little training to use.
- TMOD is accountable for the performance and cost of the science services.
- The process for customers to obtain approval to use the DSMS science services is established.
- TMOD provides an up-to-date catalogue of mature and developmental science capabilities.
- TMOD provides DSN Science configuration management consistent with an R&D environment.
- A special operations team utilizes science capabilities to perform specialized measurements in support of flight missions (e.g., delta DOR, EDL, etc.)

Interim State - Before 2006

- All of the DSMS science capabilities can be operated remotely from the customer's home institution or JPL.
- DSMS science capabilities can be run unattended using "scripts" prepared by the customer or TMOD science personnel.
- DSMS provides any and all relevant operations monitor data to its customers during and after science observations, wherever the users are.
- DSMS science capabilities are used in diverse, new, and innovative ways

Final State - After 2006

- Data is made available to the customer in near real-time electronically, i.e., no tape interface.
- DSMS's state-of-the-art, in many cases unique, science capabilities are well known and sought after by the scientific community for use in advancing NASA's science objectives.

3. ASSUMPTIONS

The Deep Space Network and other elements of DSMS will continue to be used as a science instrument.

TMOD will continually expand and enhance DSMS capabilities for direct scientific observations

TMOD will respond to changes in NASA's science objectives, customer demand, by developing new DSMS capabilities. Other science capabilities will be developed to assist research and development of other, new DSMS

capabilities e.g., telecommunications capabilities.

TMOD will enable scientists to make effective use of the DSMS for new, innovative applications.

TMOD will enable interested scientists to perform observations utilizing DSMS by providing expertise and assistance in developing new applications of DSMS and by making use of the DSMS affordable.

Science users of the DSMS are ultimately responsible for the success of their scientific observations.

TMOD's role is to support these users such that the science capabilities of the DSMS are utilized to their fullest and the observations are performed in a cost effective manner.

TMOD will work with the principal investigator of the scientific observations to maximize the value of the observing time.

Operator interfaces will be designed such that users may choose to assume operations responsibilities and execute those responsibilities with minimal training.

TMOD will customize the interface between the DSMS and its science customers when necessary to ensure affordable, effective operations.

Science customers will use standard interfaces when practical but will also have many other operations options for interaction with the DSMS. Some of these are:

- The customer provides TMOD with science objectives and TMOD performs experiment planning, implements new equipment, operates the DSMS, and analyzes data in response.
- The customer and TMOD develop an experiment plan. TMOD executes the plan and provides the customer raw or processed data.
- The customer and TMOD personnel collaborate in experiment operations.
- The customer operates the DSMS using operations scripts, remote access, and/or onsite.
- The customer provides and operates equipment to augment the DSMS science capabilities.

TMOD will share with its science customers all information concerning the performance of DSMS equipment relevant to the customer's observations.

The DSMS Science Service System operations and performance will be open to its customers to the extent possible, even to the extent of providing onsite access to equipment.

4 .OPERATIONS ROLES AND OPERATIONS TEAMS

There are three classes of science customers of the DSMS.

1. **Institutional Customers** such as an existing mission (like the US Space VLBI Project) or an outside organization (such as the European VLBI Network);
2. **Pre-Approved Investigators** such as Radio Science investigators associated with TMOD supported flight projects, tasks under existing RTOPs which require the use of DSMS facilities, and investigators operating under Host Country or similar agreements;
3. **Guest Investigators** who submit proposals directly to TMOD for use of the DSMS Science capabilities.

Institutional Customers and Pre-Approved Investigators have already been approved on the basis of experiment proposals to other organizations.

An Experiment Team will plan and perform operations in support of experiments. The composition of the Team and the extent of each team member's involvement will depend on the nature of the experiment, the extent of modification to DSMS equipment, and the judgment of the Experiment Principal Investigator.

A Standing Experiment Team may be created to provide support of long term observation programs (e.g., radar observations of asteroids) or the use of standard science services (e.g., VLBI). In the case of standard science service, a

Standing Experiment Team will be created to develop the standard service. A definition of the service, how the service will be delivered (e.g., file interfaces), and the cost of the service will be documented in an Experiment Plan. TMOD science management will appoint a PI to lead the Standing Experiment Team. Typically the PI will be a scientist who uses that service. The PI would then choose the Experiment Team with TMOD concurrence. The Experiment Team would also be responsible for updating the Experiment Plan if the need arises such as in response to customer demand, new technology, or budget considerations.

The **Experiment Principal Investigator** is the lead investigator in charge of the experiment and will lead the Experiment Team. In most cases, the Experiment PI is the scientist who proposed and received funding and approval for the experiment.

Experiment Co-Investigators assist the PI as established in the Experiment Plan (see below).

If they are required, **DSMS Collaborators** are DSMS personnel assigned to the Experiment Team who have cognizance of the DSMS capabilities to be used and will assist in experiment design, operations planning, and experiment execution. They may operate the equipment remotely or onsite. The DSMS Collaborators determine the level of DSMS support that can be committed to the experiment in the context of other DSMS commitments and the costs of the services to the user. TMOD science management appoints and funds the collaborators working on the experiment with concurrence from the PI.

The TMOD R&D Configuration Policy Board has responsibility for all the R&D equipment. Changes may be made to the R&D equipment, such as the addition of new equipment for a particular experiment, but are subject to the policies of this Board.

Any experiment, which requires changes to standard DSMS equipment, will be considered an R&D activity and is not covered by this operations concept.

Complex Science Engineers have special training in operations of DSMS in specialized modes for scientific observations and are available for assistance in experiment planning and operations onsite. The **Complex Director** will appoint the particular individuals working on an experiment.

5. CUSTOMER INTERFACES

The interfaces between TMOD and the science users of DSMS are described below.

A potential Guest Investigator submits an **Experiment Proposal** to the TMOD Science Manager. The proposal includes

- science objectives,
- observation strategy,
- proposed equipment configuration,
- an operations plan,
- a budget for special TMOD support, if needed,
- a plan for publication and release of data, and
- a public outreach plan.

The Experiment Plan is a comprehensive plan for performing the observations described in the Proposal. The Experiment Plan also describes the criteria for assessing the quality of the service. The Experiment Team determines the exact form and contents of the plan and the entire Team approves the completed plan.

The operations interface can take many forms (see Section 2) and will be documented in the Experiment Plan.

Data delivery methods will be described in the Experiment Plan.

6. OPERATIONS SCENARIO

The following describes the operations scenario for science users of the DSMS.

Step 1 - Experiment Planning

Scientists interested in using the DSMS for observations investigate the catalog of science capabilities and develop ideas for science observations. In this process, TMOD personnel can be consulted for additional information and advice on observation strategy, operations planning, and budgets.

Step 2 - The Experiment Proposal

Science users receive permission to use the DSMS on the basis of their experiment proposals. Institutional and pre-approved investigators submit proposals to other organizations. A guest investigator (only) submits an experiment proposal to the TMOD Science Office, which will arrange for the proposal to be evaluated on the basis of compatibility with DSMS capabilities, scientific merit, feasibility, and in the context of other scientific observations. The TMOD Science Manager will determine the level of review appropriate for each proposal based on the required TMOD resources to accomplish the proposed observations. If required, peer reviewers will have expertise in the research area of the proposal, be knowledgeable about DSMS capabilities, and be impartial. On the basis of the review, the proposal will be judged "accepted", "accepted with conditions", or "rejected". In the case of proposals accepted with conditions, the conditions under which the proposal will be accepted will be clearly defined. In the case of rejected proposals, the proposal response letter will state the reasons the proposal was not accepted. Proposers should allow six weeks after TMOD's receipt of the proposal for the proposal to be evaluated.

There are special cases where the six-week evaluation period will be waived. In these cases, such as an important target of opportunity requiring quick response, the manager of the TMOD Science Office can grant quick approval and re-allocate resources. Also, proposers can request pre-review of proposals for targets of opportunity (e.g., potential radar observations of asteroids yet to be discovered).

Step 3 - The Experiment Plan

After an experiment is approved, an Experiment Team will be created. Its members and their roles are described in Section 5. The Experiment Team's first task is to prepare an Experiment Plan. This plan will describe how the experiment will be performed including the roles and responsibilities of each Team member. The Experiment Team determines the plan's form and content and the entire Team approves it. The plan could include:

- The experiment equipment configuration;
- The relative responsibilities among the Team members and their organizations;
- An operations scenario;
- Experiment preparations and testing;
- Experiment constraints such as scheduling;
- The budget for the experiment including a list of committed special TMOD services and their cost (TMOD does not fund science investigations. However, special TMOD costs in support of the investigations, like the salaries of TMOD-assigned collaborators, must be identified.)
- Service quality metrics
- Public outreach plan.

Step 4 - Experiment Preparation

Preparations will proceed according to the Experiment Plan. Preparation could include:

- Modification of DSMS equipment,
- Installation of user supplied equipment,
- Interface testing between DSMS and user supplied systems,
- Data flow testing,
- Operations readiness testing, and
- Training of Operations personnel, if needed.

Step 5 - Experiment Execution

The planned scientific observations are performed.

Step 6 - Data Delivery

Data from the observations delivered to the user.

Step 7 - Service Quality Assessment

After preliminary data analysis, the Experiment Team assesses the quality of the TMOD services using the service quality metrics in the Experiment Plan.

Step 8 – Data Release and Publication

The data is released to the scientific community and results are published.

Step 9 - Public Outreach

If required in the Experiment Proposal, the Experiment Team executes the public outreach plan as described in the Experiment Plan.

7. CONCLUSIONS

The DSMS Science Operations Concept enables scientists with varying degrees of expertise in the Deep Space Network's science capabilities to successfully make scientific observations. This is accomplished with a operations interface that allows the Principle Investigator to chose the level of TMOD service and participation, as well as the service quality metrics, that the PI believes are appropriate for the planned observations.

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